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Toasted, roasted and grilled? Walking the talk on green monetary policy

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EXECUTIVE SUMMARY[i]

- **At this week's ECB Forum on Central Banking in Sintra, climate change risks and their impact on monetary policy will feature prominently on the agenda.** One of the awarded academic papers investigates how the transition to a net-zero emissions economy can affect the transmission of monetary policy. This follows on the heels of ECB President Lagarde's recent comments at the Future Investment Initiative in Riyadh/Saudi Arabia last week that "we will be toasted, roasted and grilled" if societies fail to effectively tackle climate change. Since mid-2022, the ECB has already begun to include climate-change considerations in its monetary policy strategy by accounting for climate change in its corporate bond purchases, collateral framework, disclosure requirements and risk management.

- **Taking cues from the discussion at the Sintra Forum, we examine whether its "climate talk" (and associated actions) has had an impact on ESG bonds.** ESG bonds tend to trade at a negative premium (i.e. lower yields) than regular bonds, i.e. investors are willing accept lower returns to hold a bond that funds sustainable investments. We use quantitative signals extracted from the ECB's communication on climate to see whether we can explain changes in this negative premium over time.

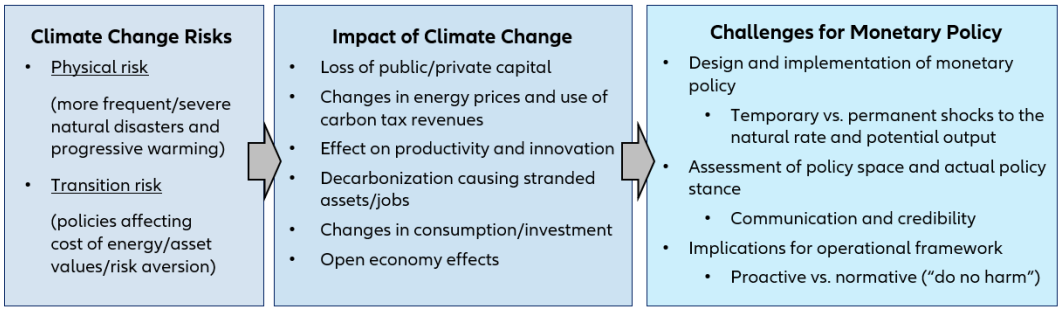
- **We find that the ECB's "climate talk" has helped increase the "greenium," i.e., the spread difference between conventional and ESG/green bonds, and, thus, created more favorable financing conditions for ESG issuers during a time of rising interest rates.** The combined effect of both concurrent and past communication explains about half of the change in the greenium on average over the last 12 months. However, over a longer time horizon, general macro-financial conditions diminish the impact of the ECB's "climate talk" on the greenium.

- **Walking the talk seems to pay off for the ECB.** Asset purchases and its collateral framework can be very powerful. By acknowledging and addressing climate-related risks in its operating framework, the ECB can fulfill its mandate of maintaining price stability while supporting the broader economic objectives of sustainable development and financial stability.

Climate change has far-reaching macro-financial implications that matter for central banks

At the ECB's Forum on Central Banking in Sintra this week, it is no surprise to see climate change risks and their impact on monetary policy feature prominently on the agenda. One of the awarded academic papers (Patozi, 2023) investigates how the transition to a net-zero emissions economy can affect the transmission of monetary policy, considering that climate change can significantly affect macroeconomic outcomes.[1] This follows on the heels of ECB President Lagarde's recent comments at the Future Investment Initiative in Riyadh/Saudi Arabia last week that "we will be toasted, roasted and grilled" if societies fail to effectively tackle climate change.

Figure 1: Macro-financial impact of climate change and implications for monetary policy



Sources: Jobst (2020), Allianz Research

Climate change risks can impact central bank mandates in three ways (Figure 1): (1) the design and implementation of monetary policy (e.g. temporary or permanent impact on the natural rate/potential output), (2) the communication of the policy stance (e.g. divergence of headline and core inflation caused by negative supply side shocks due to natural disasters and/or higher energy prices) and (3) financial risk management in its operational framework (e.g. accounting for climate risk exposures of counterparties in its collateral framework).

Many central banks have already begun to incorporate climate-related risks into their monetary policy frameworks. For example, central banks can incorporate climate-related risks into their economic models and forecasting frameworks to better understand the potential effects on growth, inflation and employment. This can help inform their policy decisions, including setting interest rates and managing liquidity in the financial system. Additionally, they can incorporate climate factors into their asset-purchase programs and collateral frameworks, promoting investments in sustainable assets while discouraging those with high carbon footprints. In this context, central banks can foster climate-related disclosures and transparency by encouraging financial institutions to report on their exposure to climate risks. This enables

[1] *For instance, the physical risks associated with climate change, such as extreme weather events and resource scarcity, can disrupt economic activity, damage infrastructure and lead to productivity losses. These disruptions can hamper economic growth and exacerbate inflationary pressures due to supply-chain disruptions and increased production costs. The transition to a low-carbon economy through climate-change mitigation efforts can also have profound macroeconomic implications. Policies aimed at reducing greenhouse-gas emissions may require significant adjustments in various economic sectors and associated structural changes. This transition can impact employment in industries that may experience job losses while others emerge or expand. It can also affect inflation dynamics as prices of carbon-intensive goods and services rise, influencing the overall price level.*

market participants to make informed decisions and facilitates the allocation of capital towards environmentally sustainable activities.[2]

What has the ECB done so far?

The ECB can play an importance role in facilitating Europe's green transition by adjusting its monetary policy tools and strategies. As part of its recent *Strategy Review*, the ECB has completed a comprehensive assessment of how climate change impacts its mandate. While the ECB's primary mandate is to maintain price stability, it also has a secondary objective of supporting the general economic policies of the EU, including sustainable development.

In July 2021, the ECB presented an action plan to include climate change considerations in its monetary policy strategy – without affecting its primary mandate of price stability. Unlike most other central banks (Appendix, Box 1), the ECB does not want to address climate change only from a risk management perspective but as a monetary-policy maker that can affect investment and saving decisions in time (now rather than later), space (in Europe rather than elsewhere) and sectors (depending on their positive contribution to climate mitigation).[3,4]

In July 2022, the ECB began accounting for climate change risks in its corporate bond purchases, collateral framework, disclosure requirements and risk management. These measures aim to reduce financial risk related to climate change on the Eurosystem's balance sheet, encourage transparency and support the green transition of the economy. The concrete measures include:[5]

- *Rebalancing corporate bond holdings* (from October 2022): Gradual decarbonization of corporate bond holdings through reinvestment of redemptions towards issuers with better climate performance (until end-June 2023 after the ECB announced the end of partial reinvestments until end-June 2022), together with the publication of climate-related information on corporate bond holdings (as of the first quarter of 2023) (Box 1 below).

- *Amending the collateral framework* (before end-2024): Limiting the share of assets from issuers with a high carbon footprint that can be pledged as collateral to access central bank money to reduce climate-related financial risks in Eurosystem credit operations. Additionally, since mid-2022, climate change risks will be considered in reviewing haircuts applied to corporate bonds used as collateral. Once the EU's delayed Corporate Sustainability Reporting Directive (CSRD) comes into force in 2026,

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[2] Central banks that are also integrated financial supervisors can use their prudential powers to encourage financial institutions to assess and disclose their exposure to climate-related risks to safeguard financial stability, which could impact monetary policy. By promoting sustainable finance and guiding the allocation of capital, central banks can support the transition to a low-carbon economy while mitigating financial stability risks.

[3] It identified the following focus areas: (1) macroeconomic modelling and assessment of implications for monetary policy transmission, (2) statistical data for climate change risk analyses, (3) disclosures as a requirement for eligibility as collateral and asset purchases, (4) enhancement of risk assessment capabilities, (5) collateral framework and (6) corporate sector asset purchases.

[4] On 22 September 2020, the ECB had already decided (with effect from 1 January 2021) that bonds with coupons linked to sustainability performance targets would become eligible as central bank collateral for Eurosystem credit operations and also for Eurosystem outright purchases for monetary policy purposes, provided they comply with all other eligibility criteria.

[5] In 2022, the ECB also conducted a system-wide banking climate stress test to evaluate the adequacy of capital requirements and encourage proactive risk-management practices under a wide range of climate scenarios developed by the Network for Greening the Financial System (NGFS).

the Eurosystem will only accept marketable assets and credit claims from companies and debtors that comply with prevailing climate-related disclosure requirements.

- *Enhancing climate-related risk assessment and management* (before end-2024): In addition to urging rating agencies to be more transparent about how they incorporate climate risks into their ratings, the national central banks within the Eurosystem agreed on a set of common minimum standards for how in-house credit assessment systems should include climate-related risks in their ratings.

As a potential next step, the ECB is also exploring the possibility of establishing a targeted green loan facility.[6] This facility would provide funding to banks specifically for green projects and investments, promoting environmental sustainability. However, there is still no consensus on the issue.[7] Alternatively, as the conventional TLTRO program phases out, the ECB could introduce "green TLTRO" auctions to support green lending (to governments, firms, households), especially for energy-efficiency renovations of buildings or climate investments by companies. This could be achieved by lowering risk minimum eligibility, haircuts and/or refinancing rates. A symmetric option would be to impose a penalty on carbon-intensive assets (Schoenmaker, 2019). Even if literature shows limited and/or temporary effects of collateral eligibility on asset prices before the crisis, non-standard measures targeting specific segments have been found to have an impact on credit growth and rates.[8]

Box 1: Greening the ECB's asset purchase program

The gradual decarbonization of corporate bond holdings has been the Eurosystem's first and most advanced operational climate initiative. In July 2022, the ECB committed to green its corporate bond holdings, even if this might require deviating from its long-standing objective of preserving market neutrality in monetary operations (based on the assumption that current market prices still do not fully reflect the economic cost of climate change risks in the future).

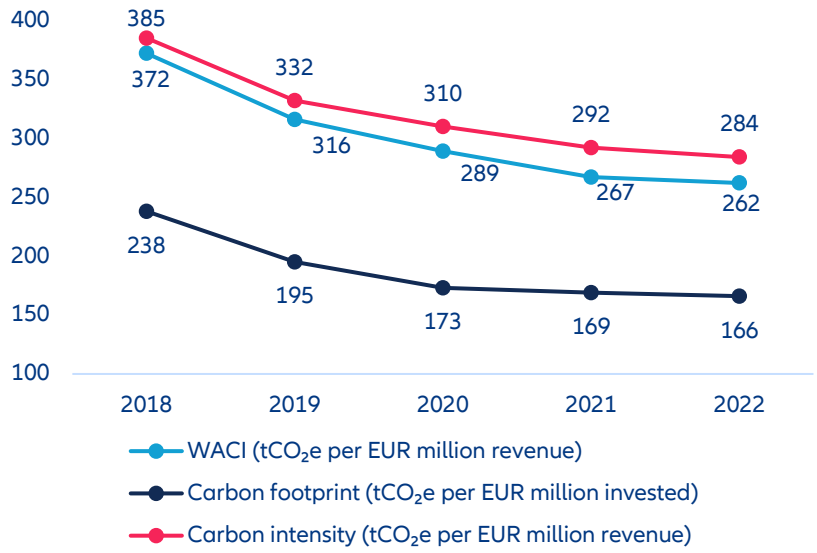
The total greenhouse gas emissions associated with the ECB's holding of corporate debt securities have declined since 2018 due to issuers' ongoing decarbonization efforts (Box 1, Figure 1). At the end of 2022, the corporate sector portfolio's share of financial exposure invested in assets of issuers with certified science-based carbon reduction targets stood at 59%, thanks to the introduction of the Eurosystem framework for incorporating climate considerations into corporate sector purchases. Since only 42% of all eligible corporate issuers have carbon-reduction targets, the ECB's corporate debt holdings are skewed towards more ambitious issuers (Box 1, Figure 1).

[6] *See Schnabel, I., 2023, "Monetary Policy Tightening and the Green Transition"*

[7] *ECB's President Christine Lagarde, for example, has said that she is in favor of the ECB setting up a green facility along the lines of the Japanese and Chinese central banks (see Green Swan conference, 31 May-1 June 2022). However, Isabel Schnabel, a member of the ECB's Executive Board, believes that such a facility would be difficult to implement in practice as, for example, many banks do not differentiate loans by category.*

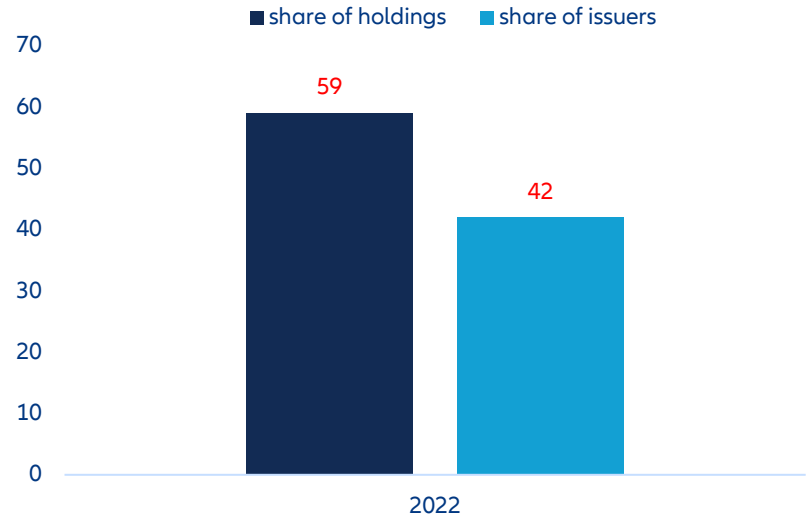
[8] *Further extending the scope of eligible assets to riskier green assets would create limited risks for the central bank as it has unlimited liquidity (Bindseil and others, 2017). These options would likely come at higher operational costs for central bank,s which would have to enhance internal credit assessment capabilities further.*

Box 1, Figure 1: Climate-related metrics on the Eurosystem's corporate sector portfolios (2018-22)



Sources: ECB, Allianz Research

Box 1, Figure 2: Share of holdings and issuers in the ECB corporate sector portfolios with science-based carbon-reduction targets (December 2022) (%)



Sources: ECB, Allianz Research

In addition to the greening of conventional corporate bonds, the ECB is also an active buyer of green bonds. It has purchased more than 20% of the current stock of euro-denominated green bonds as part of its asset-purchase program, and many green bonds are eligible as collateral in Eurosystem open-market operations. However, the green bond market is still small and relatively illiquid. While European issuance of green bonds has been expanding rapidly, accounting for nearly half of global issuance, only 15% of total debt issuance in Europe is

"green".[9] So the current size of the market is unlikely to provide the scale required for the transition towards a carbon-neutral economy at the pace required to stimulate investment and innovation. However, the evolving regulatory framework for green bonds, including the newly adopted EU Green Bonds Standard, could catalyze the market and also mitigate the risk of accountability challenges if the ECB would make its involvement in the green bond market more explicit.

Words speak as loud as actions ?

Against the background of the ECB's evolving green monetary framework, we examine whether its related communication has impacted the pricing of ESG bonds relative to conventional bonds.[10] While the ECB's concrete actions were too recent to draw firm conclusions, it is possible to assess whether its "green talk" may have already influenced investors in the way they price corporate bonds. After all, there is a large literature showing that central bank communication significantly influences asset markets.[11]

We use Natural Language Processing (NLP) techniques and dictionary analysis to extract two quantitative signals – topics of interest and implicit sentiment – as proxy measure of the ECB's communication on green monetary policy. In recent years, the ECB has broadened the scope of its information disclosure, speeches and press statements beyond the traditional topics, such as monetary policy and price stability. Extending the model by Fortes and Le Guenedal (2020) to a longer time period (until May 2023) confirms that structural challenges, such as climate change, have become increasingly prominent in the ECB's communication since 2021, together with social topics such as gender equality (Figures 2 and 3). Sentiment analysis using a lexicon of general and financial market-specific terms also suggests that the tone of ECB speeches shifted from optimistic to neutral over time (Figures 4).[12]

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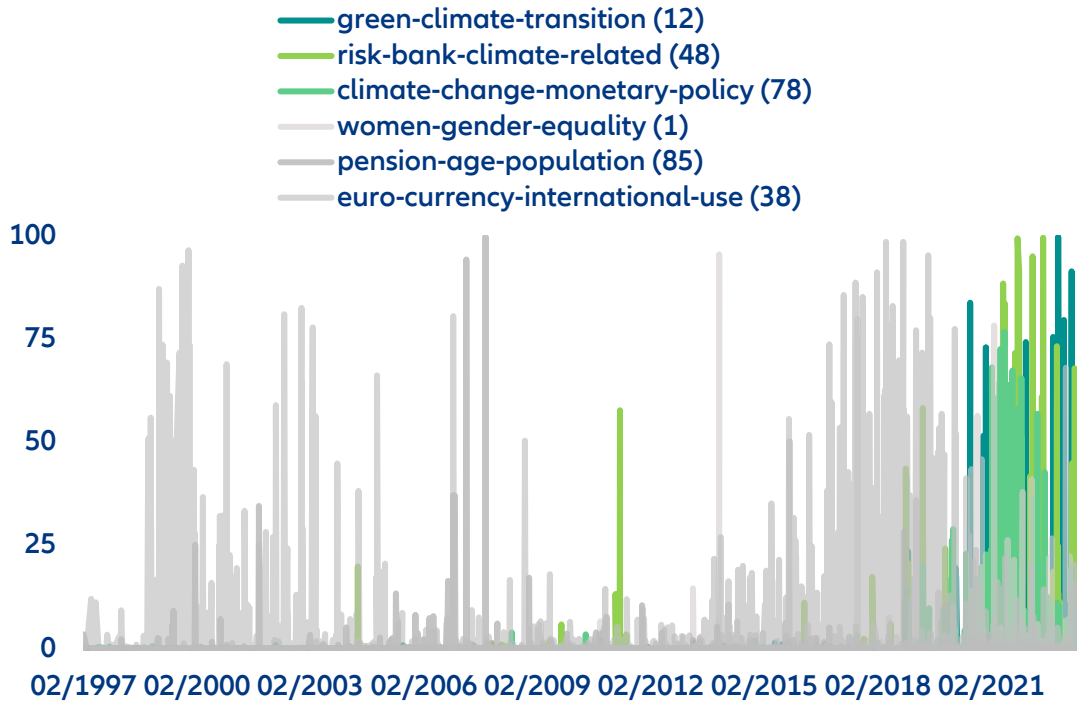
[9] Based on the latest issuance data, 15% of new investment grade (IG) corporate debt issuance in EUR was green in 2022 (vs. 3% in USD). The green share of EUR IG corporate debt outstanding was around 7.5% in 2022. In terms of index-eligible issuance (based on the ICE Bank of America Euro Corporates Index), more than 20% of the issuance was "green" last year.

[10] Green bonds are financial instruments with a clear and fixed objective of financing projects related to the environment and the transition to a low-carbon economy. Together with social and sustainability-linked bonds, they are a subset of the ESG bond sector. The European Investment Bank was the first European issuer of a green bond in 2007. Since then, the market has grown substantially, especially prompted by the introduction of the ICMA Green Bond Principles (GBP) in 2014. Annual issuance exceeds EUR400bn in the Eurozone, of which about two-thirds are sponsored by the private sector (Figure 5).

[11] See, for instance, Bernanke and others (2004), Blinder and others. *(2008) as well as Schmeling and Wagner (2019).*

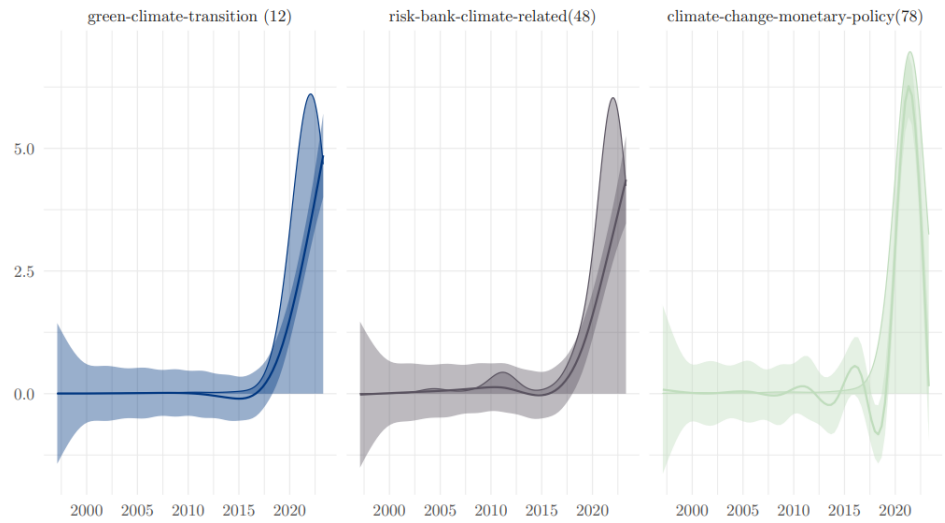
[12] The literature also suggests that the sentiment in central bank speeches is a potential market driver. For instance, Schmeling and Wagner (2019) found that a positive tone in the ECB's press conferences is associated with higher equity market returns, lower volatility risk premia and lower credit spreads.

Figure 2: Probability of key topics of ECB communication (identified by natural language processing) (%)



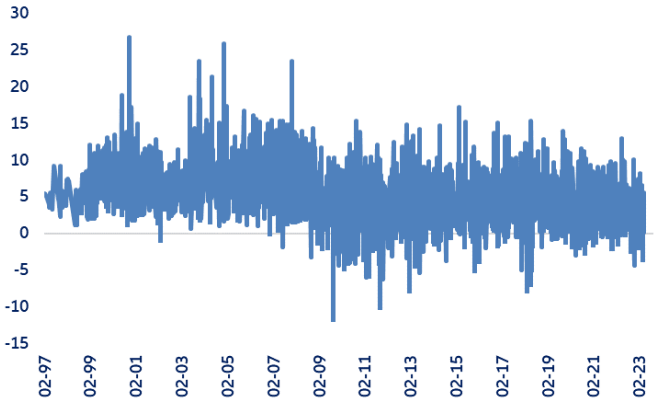
Sources: Allianz Research. Note: based on Fortes and Le Guenedal (2020) who adapted the structural topic model (STM) developed by Roberts, Stewart and Tingley (2019) to estimate the main topics that characterize a corpus of text and their corresponding proportions; the methodology is applied to ECB communication (press conference, speech and interview) from January 1997 to May 2023 to identify the main topics and extract quantitative topic signals over time. The advantage is that it provides a clear output. In total 85 topics were identified.

Figure 3: Probability density of climate-related topics in ECB communication (identified by natural language processing) (%)



Source: Allianz Research. Note: based on Fortes and Le Guenedal (2020) who adapted the structural topic model (STM) developed by Roberts, Stewart and Tingley (2019). The figure highlights the climate-related topics from the ECB's communication and the top words associated with them.

Figure 4: Language tone signals (polarity component) of ECB communication



Sources: Several lexicons, Allianz Research. Note: Based on the computation of 18 scores using general lexica (e.g., AFINN, BING, and NRC) and a specialized financial dictionary (Loughran-McDonald). Applied to different styles used by the ECB - formal and informal. Principal component analysis (PCA) is used to reduce dimensionality.

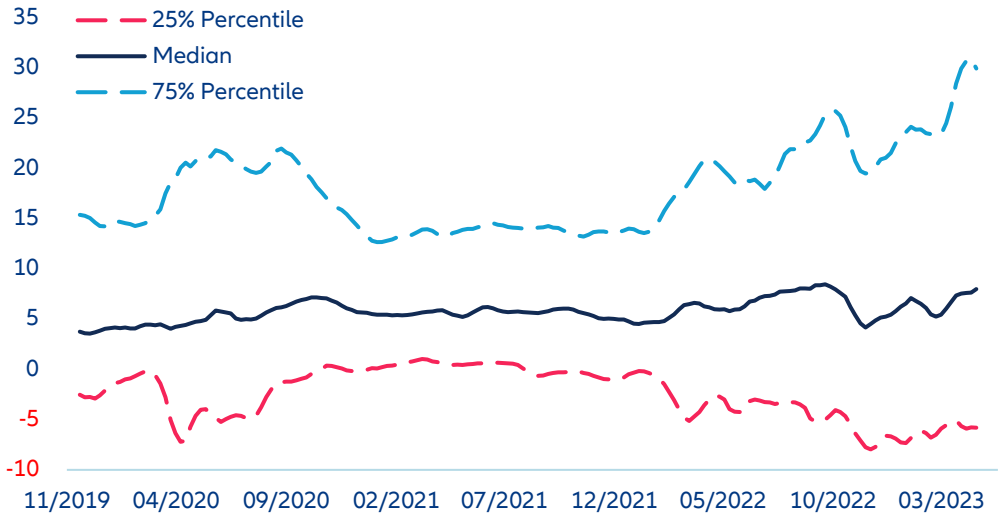
Have ECB actions influenced asset prices?

We use the derived signals to examine whether the ECB's "climate talk" influences asset prices. Following the approach taken by Pietsch and Salakhova (2022), we complete a pairwise mapping of outstanding green/sustainability bonds ("ESG bonds")[13] to conventional bonds

[13] *Green bonds are financial instruments with a clear and fixed objective of financing projects related to the environment and the transition to a low-carbon economy. They are a subset of the ESG bond sector together with social bonds, serving social issues and sustainability bonds that combine green and social*

issued by corporates and government agencies (such as national development banks) to create a time series of spread and duration differences for a portfolio of bonds. ESG bonds tend to trade at a negative premium (i.e. lower yields) than regular bonds (Figures 5-6). Hence, investors are willing to accept lower returns to hold a green bond ("greenium").[14] We then use the signals extracted from the ECB's communication on climate to see whether these explain changes in the greenium over time. In a subsequent step, we apply the same approach to a smaller sample of only green bonds to corroborate our results (Annex).

Figure 5: Monthly average OAS difference between conventional and ESG bond pairs (bps)

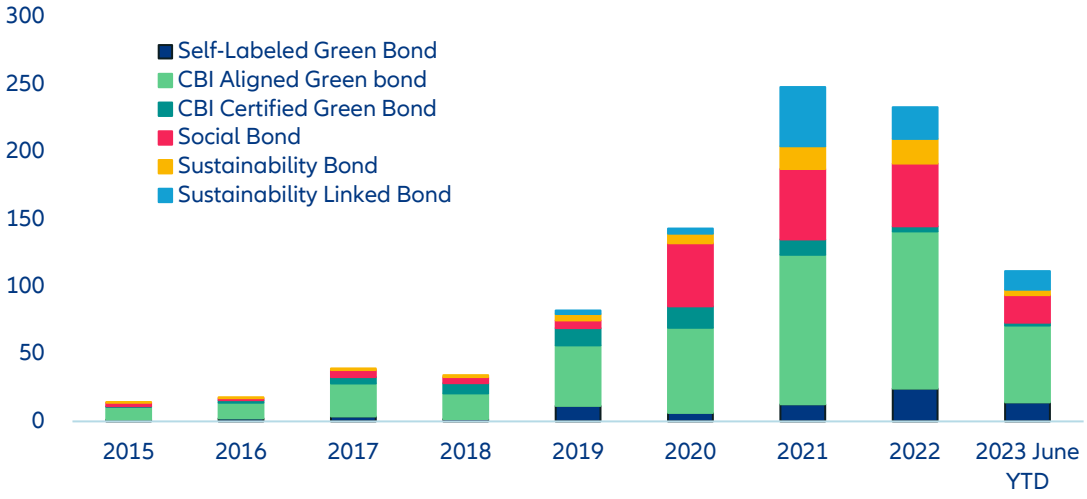


Sources: Refinitiv, Allianz Research

objectives. The European Investment Bank was the first European issuer of a green bond in 2007. Since then, the market has grown substantially, especially after the introduction of the ICMA Green Bond Principles (GBP) in 2014. Annual issuance exceeds EUR 400bn in the Eurozone, of which about two-thirds are sponsored by the private sector (Figure 6).

[14] Related literature confirms the existence of a small but persistent greenium, which tends to be more pronounced when bonds are issued by governments or supranational entities, denominated in EUR or USD, or corporate bonds with very large issue sizes (Kapraun and Scheins, 2019; Fatica and others, 2019). For the purpose of this paper, we use the term "greenium" loosely to describe the spread difference of sustainability-related bonds to regular bonds.

Figure 6: ESG bond issuance by corporates/agencies in the Eurozone (EUR billion)



Sources: Refinitiv, Allianz Research

We specify a simple ordinary least squares (OLS) regression model, which is specified as:

$$\Delta\, greenium = \alpha + \beta_1\, \Delta\text{Euribor}_t + \beta_2\, \Delta\text{10Y\_Bund}_t + \beta_3\, \Delta\text{duration\_diff}_t + \beta_4\, \Delta\text{VIX}_t + \beta_5\, (\text{T*S})_t + \beta_6\, (\text{T*S})_{t\text{-}1} + \beta_7\, (\text{T*S})_{t\text{-}2},$$

where the climate-related topic and sentiment signals extracted from the ECB's communication are *T* (probability of presence of a climate/green topic in the ECB's discourse) and *S* (sentiment in the selected ECB mode of communication). We use option-adjusted spreads (OAS) instead of bond yields to calculate the greenium to better capture the return of a bond in excess of the risk-free rate and its embedded options. We also include common explanatory variables, such as the (1) risk-free rates (3-month Euribor and 10-year German Bund yields, (2) the average duration difference between the bond portfolios (including sectoral differences) and (3) the implied equity market volatility to a measure of risk aversion and/financial stress.

We estimate the model using monthly changes in the greenium over a one-year time horizon (May 2022-May 2023). The sample start date coincides with the ECB's step-implementation of tangible climate actions (including rebalancing of corporate bond purchases and the amendment of the collateral framework). The choice of a shorter time window helps maximize the number of bonds in the sample (272 pairs) but also comes with the tradeoff between the quality of the target variable (which gets noisier as the time period shrinks) and statistical robustness (which might increase with a longer time window and more observations).[15]

We find that the ECB's "climate talk" has helped increase the greenium, creating more favorable financing conditions for ESG issuers during a time of rising interest rates. Our model estimates suggest that the ECB's communication on climate has had a persistent positive effect on the spread differential between conventional and ESG bonds. The combined effect of both concurrent and past communication explains about half of the change in the greenium on average over the last 12 months (Figure 7). The effect is even stronger (albeit more short-lived) if we restrict the sample to green bonds only (at the expense of lower

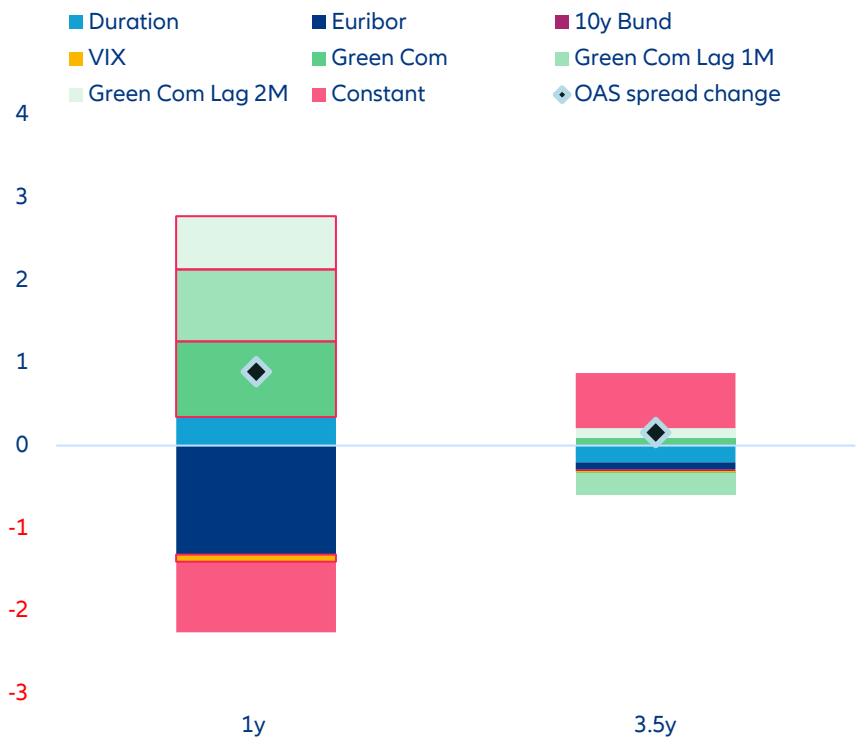
[15] *Lengthening the time horizon reduces the observations for constructing the greenium to 87 pairs for 3.5 years.*

robustness). Changes in the duration between conventional and ESG bonds and higher market uncertainty have also increased the greenium, which might confirm that green bonds tend to be less affected by market downturns (as suggested by the literature).[16] However, this result has to be considered very carefully due to the short time window and the monthly frequency of observations (which reflect strong market sensitivity to the ECB's communication series, rendering the use of daily or weekly frequency for our analysis less useful). The strong results for the short time window might also reflect rising demand for green bonds, which echoes the findings in Pietsch and Salakhova (2022). Indications of a higher issuance premium for green bonds over this time period further supports the positive financing impact of the ECB's "climate talk."

Over a longer time horizon, general macro-financial conditions seem to diminish the impact of the ECB's "climate talk" on the greenium. Using a sample covering 3.5 years, the greenium remains stable but we find no significant effect for the ECB's communication on its changes. Other explanatory variables also lose explanatory power. However, since the underlying sample of matched bonds differs from the one used for the one-year time horizon, the estimation results should be treated as additional results rather than a robustness check. Both effects might also be influenced by a deteriorating quality of bond mapping and several crisis-related regime changes, which are interesting areas for further research.

[16] Detailed output can be found in the appendix. This result focus on the ESG benchmark, for a bond portfolio only consisting of green bonds please check the appendix as well.

Figure 7: Decomposition of explanatory variables of the monthly change in greenium (sample average, bps)



Sources: Refinitiv Datastream, Allianz Research. Note: M=month(s); red borderlines indicate a statistically significant contribution of the respective explanatory variable to a change in the greenium at a probability of at least 10%. Note that the estimation results for the two time periods (1 year vs. 3.5 years) are based on different samples of mapped bonds, and, thus, are not directly comparable.

Walking the talk seems to pay off for the ECB and confirms that it can play an important role in Europe's green transition. Asset purchases and its collateral framework can be very powerful, especially once the full implementation of the EU taxonomy on sustainable activities and the EU Green Bond Standard can provide clear guidance and legal certainty. By acknowledging and addressing climate-related risks in its operating framework, the ECB can fulfill its mandate of maintaining price stability while supporting the broader economic objectives of sustainable development and financial stability.

APPENDICES

Box 1. Overview of climate change-related policy actions taken by other European central banks

Bank of England

The Bank of England acted first to combat climate-related risks and incorporated climate considerations into its monitoring and supervision mandates. Its 2021 Climate Change Adaptation sets out the approach to the risks posed by climate change to its operations and policy functions, focusing on the supervisory approach and the potential role for regulatory capital requirements. The Bank of England also published its approach to greening the Corporate Bond Purchase Scheme in the same year. And from 2022 onwards, the Bank moved towards actively supervising regulated firms to managing the financial risks from climate change. Finally, the Bank of England updated its mandate to "reflect the importance of environmental sustainability and the transition to net zero" and to bring its operations in line with the UK government's net-zero carbon strategy.

Sveriges Riksbank

The Swedish central bank supports effective climate policy in three main areas: (1) strengthening research focusing on economic sustainability, (2) adapting, in cooperation with other authorities, regulation of the financial system (and is working already on stress testing, the reporting of climate-related risks and banks' capital requirements) and (3) enhancing the management of the bank's own balance sheet.

Since January 2023, the new Sveriges Riksbank Act, also tasks the central bank to identify threats to sustainable development that affect the conditions for its operations. The recently published Climate Report describes how the Riksbank works with climate-related risks and what challenges the authority and other players in the financial sector need to address. In its asset purchases and asset management, the central bank considers the risks associated with climate change and transition. The Riksbank takes sustainability into account in the selection of assets in the foreign exchange reserves as far as this is possible, without affecting the bank's ability to carry out its main task and also reports the carbon footprint of the foreign exchange reserves.

Swiss National Bank

The Swiss National Bank (SNB) lags behing its European peers regarding the formulation of a strategic climate agenda. The SNB's has built large foreign currency reserves since 2011 (foreign currency reserves holdings amount to CHF910bn at the end of 2020). Equity investments represent 20% of the currency reserves and make the SNB an important global equity investor. However, the SNB manages its equity portfolio passively based on a strategic benchmark comprising a combination of equity indexes in various markets and therefore ESG aspects are deliberately not considered. Any move by the SNB to decarbonize its operations would have significant global implications due to the size of the central bank's foreign currency portfolio.

Details on empirical analysis and results

1. ESG bond spread analysis – portfolio construction

Data

ESG bonds do not differ substantially from conventional bonds except that their proceeds are pledged for ESG-related causes (defined by the issuer). There are multiple governance frameworks available with variable definitions of ESG eligible causes and different levels of verification. For this analysis, we relied on instruments listed in Refinitiv EIKONs ESG Bond Guide (ESGG). This universe was filtered for EUR denominated corporate bonds with the following criteria:

- issued before May 2021
- remaining time to maturity between 1 and 30 years as of May 2023
- issuance volume above EUR10mn
- fixed/zero coupon
- seniority type is senior unsecured debt
- issuer located in the Eurozone and debt issued in EUR
- issuer rating between AA and BBB
- part of the ECB collateral framework
- agency or corporate debt

The corresponding universe of potential non-ESG bonds was constructed applying the same criteria on bonds listed in EIKONs Bond Guide (BNDG) and were not already part of the ESG universe.

Mapping methodology

The final ESG bond universe consists of 272 ESG bonds and 1,121 conventional bonds. For all potential pairs a similarity weight has been defined penalizing any difference between:

- Duration
- Domicile
- Rating
- Sector
- Issuer
- Issuer Type (agency vs. corporate)
- ECB haircut

Afterwards the optimal combination of pairs based on the weighting table is constructed using the Kuhn–Munkres algorithm for an optimal solution on the bipartite graph.

Quality assurance measures and data enhancement

Bonds with incomplete option adjusted spread (OAS) time series or spurious spikes in the duration timeseries in the observation period have been removed. This reduces the bond universe to 87 ESG bonds and 636 conventional bonds when the longer timeframe between 21 October 2019 and 21 April 2023 is applied. For this longer timeframe, the mapping algorithm has been rerun, leading to new optimal pairings.

Consideration

The quantification of the greenium based on the matched bond pairs needs to be treated with caution. The spread difference varies significantly across pairs of ESG and regular bonds and is only observable as the average or median of a broad portfolio.[17] This can be partially explained by the large heterogeneity between individual bonds and issuers, which makes it challenging to find sufficiently suited bond pairs. All data used for pairing ESG and conventional bonds was retrieved in May 2023 without taking into account rating migrations or bond restructurings during the sample period. Some issuers even receive post issuance certification of ESG bonds, which adds additional noise to the comparison. In addition, some option-adjusted spreads might only be indicative since some bonds are traded only occasionally and pricing mostly relies on models from data vendors.

2. Detailed regression results

Appendix Table 1: Regression results for change in option adjusted spreads (conventional – ESG bonds only)

Timeframe	**May 2022 – May 2023**	**Oct. 2019 – May 2023**
Frequency	Monthly	Monthly
Sample size (bond pairs)	272	87
R^2	0.978	0.283
Euribor	-0.061 (0.160)	-0.013 (0.731)
10y Bund	-0.008 (0.376)	0.017 (0.402)
Duration	0.224 (0.431)	-0.346*** (0.004)
VIX	0.194* (0.069)	-0.021 (0.628)
Green Communication	**1.064* (0.057)**	**0.065 (0.811)**
Green Communication Lag 1M	**1.012* (0.079)**	**-0.205 (0.436)**
Green Communication Lag 2M	**0.749* (0.073)**	**0.092 (0.725)**
Constant	-0.853 (0.431)	0.666 (0.417)

Sources: Refinitiv, Allianz Research. Note: *p<0.1; **p<0.05; ***p<0.01.

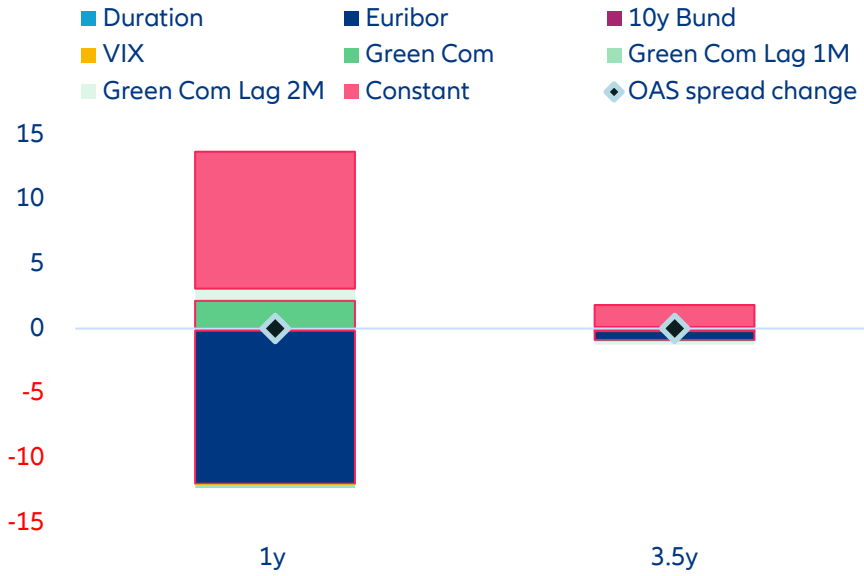
[17] *Over the total sample time period (3.5 years), the greenium ranges from -10bps (25th percentile) to +35bps (75th percentile). Only seven bond pairs exhibit a greenium of option-adjusted spreads every single day.*

Appendix Table 2: Option-adjusted spreads (conventional – green bonds only)

Timeframe	**May 2022 – May 2023**	**Oct. 2019 – May 2023**
Frequency	Monthly	Monthly
Sample size (bond pairs)	181	72
R^2	0.991	0.408
Euribor	-0.547*** (0.005)	-0.109** (0.017)
10y Bund	0.006 (0.797)	0.032 (0.182)
Duration	-0.150 (0.757)	-0.382*** (0.002)
VIX	0.204 (0.148)	0.038 (0.440)
Green Communication	**2.491** (0.022)**	**0.066 (0.832)**
Green Communication Lag 1M	**-0.270 (0.613)**	**-0.052 (0.863)**
Green Communication Lag 2M	**1.098 (0.134)**	**-0.190 (0.530)**
Constant	10.590** (0.022)	1.698* (0.075)

Sources: Refinitiv, Allianz Research. Note: *p<0.1; **p<0.05; ***p<0.01.

Appendix Figure 1: Decomposition of explanatory variables of the monthly change in greenium (sample average, only green bonds, bps)



Sources: Refinitiv, Allianz Research. Note: M=month(s); red borderlines indicate a statistically significant contribution of the respective explanatory variable to a change in the greenium at a probability of at least 10%..

Appendix Figure 1 displays the results for the green bond subset of the ESG bond benchmark. While the portfolios for the 1y observation and the 3.5y observation are constructed by updating the optimal parings, no remapping of bonds has been carried out in filtering the ESG benchmark for green bonds only. The results for 1y experiment still indicate some explanatory power of the green communication but less pronounces as for the ESG benchmark portfolio. The results for the 3.5y experiment do not show much explanatory power in our input variables to explain the monthly change in greenium.

[i] *The authors are very grateful to Maximilian Bong from Allianz Investment Management for helpful comments.*

These assessments are, as always, subject to the disclaimer provided below.

FORWARD-LOOKING STATEMENTS

The statements contained herein may include prospects, statements of future expectations and other forward-looking statements that are based on management's current views and assumptions and involve known and unknown risks and uncertainties. Actual results, performance or events may differ materially from those expressed or implied in such forward-looking statements.

Such deviations may arise due to, without limitation, (i) changes of the general economic conditions and competitive situation, particularly in the Allianz Group's core business and core markets, (ii) performance of financial markets (particularly market volatility, liquidity and credit events), (iii) frequency and severity of insured loss events, including from natural catastrophes, and the development of loss expenses, (iv) mortality and morbidity levels and trends, (v) persistency levels, (vi) particularly in the banking business, the extent of credit defaults, (vii) interest rate levels, (viii) currency exchange rates including the EUR/USD exchange rate, (ix) changes in laws and regulations, including tax regulations, (x) the impact of acquisitions, including related integration issues, and reorganization measures, and (xi) general competitive factors, in each case on a local, regional, national and/or global basis. Many of these factors may be more likely to occur, or more pronounced, as a result of terrorist activities and their consequences.

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